



Pacific Island Network Vital Signs Monitoring Plan: Phase III Report

Appendix G: Vital Signs Prioritization

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Pacific Island Network (PACN)

Territory of Guam

War in the Pacific National Historical Park (WAPA)

Commonwealth of the Northern Mariana Islands

American Memorial Park, Saipan (AMME)

Territory of American Samoa

National Park of American Samoa (NPSA)

State of Hawaii

USS Arizona Memorial, Oahu (USAR)

Kalaupapa National Historical Park, Molokai (KALA)

Haleakala National Park, Maui (HALE)

Ala Kahakai National Historic Trail, Hawaii (ALKA)

Puukohola Heiau National Historic Site, Hawaii (PUHE)

Kaloko-Honokohau National Historical Park, Hawaii (KAHO)

Puuhonua o Honaunau National Historical Park, Hawaii (PUHO)

Hawaii Volcanoes National Park, Hawaii (HAVO)

<http://science.nature.nps.gov/im/units/pacn/monitoring/plan/>

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Note:

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Introduction

The Pacific Island Network incorporated a combination of network-wide meetings, topical working groups, and individual park scoping sessions to identify potential Vital Signs along with the attributes that make Vital Signs high-quality indicators of ecosystem health. Ten topical working groups (i.e., climate, invasive species, freshwater animals, water quality, geology, landscape issues, invertebrate fauna, vertebrate fauna, vegetation, and marine) were extensively involved in collecting information to propose and refine Vital Signs. Park scoping sessions were held at each of the PACN parks to provide input on candidate attributes to monitor.

Potential Vital Signs were prioritized by staff at each park based upon four weighted criteria: (1) ecological significance (30%), (2) management significance (30%), (3) legal mandate (20%), and (4) cost-effectiveness (20%; Table 1). A database was developed to allow each park to independently rank each Vital Sign according to the criteria identified above. PACN staff provided a detailed justification statement for each Vital Sign that included information about ecological significance and legal/policy mandates. However, park staff based cost effectiveness/feasibility rankings on practical experience and expectations, and ranked management significance according to the park's priorities. The database allowed parks to review detailed information about each Vital Sign, rank Vital Signs, view Vital Sign ranking summaries, and revisit the rankings as desired.

A workshop was hosted by the PACN in March 2004 to gain input from subject area experts and network park staff about the list of proposed Vital Signs and prioritization process. A report detailing the results of the workshop, with the resulting list of 115 Vital Signs and a list of participants, may be found in Appendix O: Workshop Reports and Park Scoping Documents.

To facilitate the process of prioritization, PACN staff and the Technical Committee discussed ways of reducing the list of 115 Vital Signs for discussion at the actual prioritization meeting. The first step involved eliminating proposed Vital Signs that were duplications or were more adequately addressed as research questions, and streamlining certain substantially similar Vital Signs. The resulting list of Vital Signs was later reduced using the network ranks, park ranks, and the Vital Signs framework as tools. The criteria used for inclusion on the short list were:

- Each Vital Sign with a high network rank (less than 15) was included.
- All Vital Signs ranked within each park's top ten were included, regardless of network rank. Vital Signs ranked within any park's bottom ten were excluded, unless they also appeared in another park's top ten.
- Each Level Two category in the national framework had at least one Vital Sign:
 - When there is only one Vital Sign in the Level Two category, it is included.
 - When there are several Vital Signs within the Level Two category, and all are low-ranked (below 50, and in approximately the bottom one-third of the list), then only the highest-ranked one is included.
 - When there are several Vital Signs within the Level Two category, and at least one is ranked greater than 50, then one-third of Vital Signs in that category are included.

Table 1. Vital Signs ranking criteria.

Criteria (Weight)	Sub-Criteria	
Management Significance (30%)	<p>Very Low: Data are of interest to the public, there is an application of the data to performance (GPRA) goals.</p> <p>Low: In addition to addressing a specific management decision, data provide information that strongly supports other management decisions. The Vital Sign address a wide-spread (pervasive) resource or issue.</p> <p>Medium: The Vital Sign will produce results that are clearly understood and accepted by park managers, other policy makers, research scientists, and the general public, all of whom should be able to recognize the implications of the Vital Sign's results for protecting and managing the park's natural resources. Data will permit managers to make informed decisions.</p> <p>High: There is an obvious, direct application of the data to a key management decision, or for evaluating the effectiveness of past management decisions. Monitoring results are likely to provide early warning of resource impairment, and will save park resources and money if a problem is discovered early.</p>	
Ecological Significance (30%)	<p>Very Low: Data from the Vital Sign are needed by the parks to fill gaps in current ecological knowledge. The Vital Sign complements Vital Signs at other scales and levels of biological organization.</p> <p>Low: The Vital Sign is sufficiently sensitive; small changes in the Vital Sign can be used to detect a significant change in the target resource or function. Reference conditions exist within the region, and/or threshold values are specified in the available literature that can be used to measure deviance from a desired condition.</p> <p>Medium: The Vital Sign represents a resource or function of high ecological importance based on the conceptual model of the system and the supporting ecological literature. The Vital Sign has a high signal to noise ratio and does not exhibit large, naturally occurring variability.</p> <p>High: There is a strong, defensible linkage between the Vital Sign and the ecological function or critical resource it is intended to represent. The Vital Sign provides early warning of undesirable changes to important resources and can signify an impending change in the ecological system.</p>	
Legal/Policy Mandate (20%)	<p>Very Low: There is no legal mandate for this particular resource/Vital Sign.</p> <p>Low: The resource/Vital Sign is listed as a sensitive resource or resource of concern by credible state, regional, or local conservation agencies or organizations, but it is not specifically identified in any federal or state legislation. The resource/Vital Sign is also covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and GPRA.</p> <p>Medium: The resource/Vital Sign is specifically covered by an Executive Order (e.g., invasive plants, wetlands), a specific 'Memorandum of Understanding' signed by the NPS (e.g., bird monitoring), or specific Congressional mandates. The need to monitor the resource is generally indicated by some type of federal or state law or other general legislative mandates.</p> <p>High: The park is required to monitor this specific resource/Vital Sign by some specific, binding, legal mandate (e.g., Endangered Species Act for an endangered species, Clean Air Act for Class 1 airsheds), or park enabling legislation.</p>	<p>This criterion is part of 'Management Significance' but is purposely separated here to emphasize those Vital Signs and resources that are required to be monitored by some legal or policy mandate. The intent is to give additional priority to a Vital Sign if a park is directed to monitor specific resources because of some binding legal or Congressional mandate, such as specific legislation and executive orders, or park enabling legislation. The binding document may be with parties at the local, state, regional, or federal level.</p>
Cost Effectiveness and Feasibility (20%)	<p>Very Low: Cost effective management uses for data exist if data were available.</p> <p>Low: Partners exist for protocol development, data collection, or analysis.</p> <p>Medium: Protocol development is economically viable (or suitable protocols already exist).</p> <p>High: The Vital Sign has measurable results that are repeatable with different, qualified personnel. Actual monitoring (sampling and analysis) would be economically viable at an appropriate frequency and intensity.</p>	

In addition to Vital Signs included on the short list using the above criteria, several Vital Signs were added to the list because they involved well-established monitoring programs by other agencies monitoring air quality and volcanic activity. Using the above criteria, PACN staff created a reduced list of 51 potential Vital Signs as a starting point for discussion during the prioritization meeting of November 2004. This list was roughly half the size of the post-workshop list, yet still included the Vital Signs ranked high by both the network and individual parks, and covered a wide range of issues using the ecological organization. This reduced list is presented in this appendix. Note, to print this appendix, use legal size paper settings.

Level 1	Level 2	Level 3	Vital Sign	Network Rank	Justification	Monitoring Questions	Monitoring Method	Measures and Metrics	Notes on Merging, etc.	AMME_Rank	WAPA_Rank	NPSA_Rank	USAR_Rank	KALA_Rank	HALE_Rank	ALKA_Rank	PUHE_Rank	KAHO_Rank	PUHO_Rank	HAVO_Rank
Air and Climate	Air Quality	Visibility and particulate matter	Visibility and particulate matter	39	Under the PSD (Prevention of Significant Deterioration) program the NPS is required to monitor visibility and work to prevent any future, or remedy any existing, impairments of visibility in Class 1 areas.	Is sight distance/quality reduced? Is light extinction affected?	Aerosol filters, cameras, nephelometer	sight distance (extinction coefficient), particulate concentration		L	M	L	M	M	H	M	M	M	M	H
	Weather and Climate	Weather and Climate	Weather/ Climate	8	Weather monitoring serves to: 1. inform visitors of extreme weather conditions that may pose a health and safety risk. 2. predict the likelihood of brush fires. 3. provide baseline data (NPS-I&M guidelines) to characterize ecosystems 4. provide supportive information to other studies (hydrology/ground water/stream flow, mass wasting, etc) 5. provide data for climate mapping 6. provide indicators of changing climatic conditions. A long term meteorological monitoring program is essential to characterize the climate and to evaluate the influence of climate or climate change on ecosystems	What are current conditions? What are the different microclimates in the parks? What are ranges of weather parameters for each park? Are they changing (multiple scales)? How frequent & intense are extreme weather events, and what are temporal & spatial trends?	weather stations (RAWS, COOP, NPS-ARD), fog monitors, fuel sticks, soil moisture/temp sensors, wetness sensors, satellite data, lidar data, climate modeling, mapping, historical records	Wind, temperature, precipitation, relative humidity, fog immersion time, fuel moist/temp, soil moisture/temp, TWI, solar radiation, wetness, extreme events (cyclones, droughts, floods), ENSO, PDO	Includes P8-extreme weather events (33) & P9-climate modeling (96).	H	H	H	H	H	H	H	H	H	M	H
Biological Integrity	At-risk Biota	T&E species and communities	Rare, threatened & endangered species	7	Threatened and endangered species are an important aspect of biodiversity. Parks are mandated (Endangered Species Act, NPS Management Policies) to monitor their condition and implement conservation activities to further their recovery.	Are the numbers of Threatened, Endangered, and Species-of-Concern species represented in each park increasing, decreasing, or steady?	Presence/absence surveys, with periodic inventory for new T, E, S-o-C species. Consider including "rare" species as well.	presence/absence	summary- will be partially available from focal species VS's	H	M	H	H	H	H	H	H	H	H	H
			Rare, threatened & endangered marine animals	13	Threatened and endangered species are an important aspect of biodiversity. Parks are mandated (Endangered Species Act, Marine Mammal Protection Act, NPS Management Policies) to monitor their condition and implement conservation activities to further their recovery.	What are trends in distribution & abundance of protected marine species or selected species of concern? What are the trends in recruitment and growth & survival rates for those species selected? Are changes and trends deleterious, and can we control or reduce threats to these populations?	Population surveys, transects, quadrats, mapping, marine mammal surveys, periodic telemetry	Abundance, demography (where appropriate), distribution, recruitment, growth, survival. Prevalence of disease, pathogens, other population threats. Qualitative data including general health		M	M	H	H	H	M	M	M	H	H	H

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Biological Integrity	At-risk Biota	T&E species and communities	Rare, threatened & endangered terrestrial invertebrate populations	12	Threatened and endangered species are an important aspect of biodiversity. Rare invertebrates frequently exhibit characters that are unique for their group and thus evolutionarily significant on a global scale. Parks are mandated (Endangered Species Act) to monitor their condition and implement conservation activities to further their recovery. Those designated Species of Concern and other rare species also form a major part of the natural resources parks are mandated to protect.	What are trends in distribution, abundance, other population characteristics, and habitat? Are threats changing? If so are changes deleterious, and can we control or reduce threats to these populations?	Population surveys (including demographics), transects, plots, mapping	Abundance, density, demographics (size/age, structure, reproduction, recruitment, etc), distribution, documentation of other population threats		M	L	H	M	H	H	H	H	H	H	M
			Marine fish communities	24	Fish serve a variety of ecological functions that affect ecosystem productivity and sustainability. Fish assemblages can act as indicators of general reef health and provide an early warning of environmental stress and potentially ecosystem change.	What are the trends in community composition & distribution in selected communities?	Transects, distance sampling, timed swim counts	Relative abundance, demographics, diversity		M	H	H	H	H	L	M	M	H	H	L
	Focal Species or Communities	Freshwater communities	Focal freshwater animal species	31	Some species are sensitive to environmental change processes, both natural and anthropogenic, and can act as indicators of specific changes. The parks are required to maintain populations of native species; several freshwater animals are also listed as threatened or endangered. Monitoring the growth, distribution, and reproductive dynamics of more sensitive species provides information that may act as an early warning for the welfare of the target species as well as that of associated species.	Is species present? If so, what are trends in population numbers, reproduction, distribution and density? Includes shrimp, fish, molluscs and insects.	Periodic quadrat netting/trapping, larval drift netting, visual transect censuses, mapping.	presence/absence, trends in abundance of different size/age classes, distribution and density		M	L	M	NA	H	H	M	M	H	M	M
			Freshwater animal communities	19	Properties of faunal assemblages and populations may be important indicators of environmental change because fauna serve a great diversity of ecological functions that affect ecosystem productivity, resilience, and sustainability. Aquatic fauna also are desirable subjects for long-term ecological monitoring because they have public appeal, and changes in the park's fauna are likely to garner a high level of public interest and generate support for corrective or remedial management actions.	What species are present? Are there long-term changes in native fish and aquatic invertebrate communities (composition, species richness, presence of aliens, etc.)?	Population surveys, periodic quadrat netting/trapping, visual transect censuses, plots, mapping.	Trends in community diversity, density over time, abundance, demographics, distribution		M	H	M	NA	H	M	H	H	H	H	L

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Biological Integrity	Focal Species or Communities	Intertidal communities	Intertidal community	18	Intertidal species are adapted to survive extreme environmental conditions however they are very vulnerable to effects from coastal land-use & development. Assemblages may be important indicators of environmental change. Tidepools serve as nurseries for important coral reef species. Most PACN parks contain an intertidal zone, either adjacent to or within their boundary. The intertidal region also has cultural significance for many Pacific Islands.	Are there long-term changes in selected communities' composition, distribution and cover? Are changes in community composition correlated with shoreline change?	Population surveys, transects, quadrats, mapping	Abundance and trends of selected assemblages or groups, evenness, richness, distribution, assemblages of foundation species, substrate type	Includes M2-Intertidal landscape pattern (44)	M	M	M	H	H	M	M	M	H	H	L
		Marine communities	Benthic marine invertebrate community	25	Coral reefs create favorable habitat for many organisms becoming centers of biodiversity; therefore community dynamics are important indicators of environmental change. Many pieces of legislation pertain to coral reef conservation. The Coral Reef Conservation Act (2000) was created to preserve, sustain, and restore the condition of coral reef ecosystems, while promoting wise management and sustainable use of these valuable marine resources.	Are there long-term changes in benthic community diversity (abundance and composition) and distribution of selected communities? What are the community dynamics? Includes both sessile & motile organisms.	Transects, quadrats (including photo, video)	Species composition & counts, percent cover of species, diversity, density/abundance, rugosity, coral growth rates		M	H	H	L	H	L	M	M	H	H	L
		Marine invertebrates	Focal marine invertebrate species	14	Monitoring population dynamics of sensitive species may act as an indictor of general population health and as early warning of environmental change. When subject to population outbreaks some invertebrate species can cause significant biological disturbances to coral reef ecosystems. Parks are required to maintain many of these native populations. Some of these species are important to monitor if they are also harvested. Many mandates exist for the protection of coral reefs.	What are trends in abundance, distribution of selected focal coral and/or invertebrate species? If applicable/selected what are the trends in reproductive indexes, growth, survival and recruitment of selected species?	Population surveys, transects, quadrats (photo and/or video), mapping	frequency/density (number per unit area), distribution, growth rates, survival, recruitment rate, reproductive index. Qualitative data, including general health		M	H	H	H	H	M	M	M	H	H	L

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Biological Integrity	Focal Species or Communities	Terrestrial communities	Focal terrestrial vertebrate species	50	Properties of faunal assemblages and populations may be important indicators of environmental change because fauna serve a great diversity of ecological functions that affect ecosystem productivity, resilience, and sustainability (Walker 1992, Risser 1995, Marcot et al. 1998). For example, apex seabird predators can be good indicators for monitoring. Terrestrial fauna also are desirable subjects for long-term ecological monitoring because they have widespread public appeal, and changes in the park's fauna are likely to garner a high level of public interest and generate support for corrective or remedial management actions.	Are selected native vertebrate communities or guilds changing? This includes changes in abundance of selected species (determined from population surveys), and/or changes in the identity and number of species present in the community or guild of interest (determined from presence/absence monitoring).	Population surveys, presence/absence surveys. Periodic inventories focused on picking up new species records (especially T, E, S-o-C species, and seabird colonies) and/or locations.	Within defined areas or specified communities: abundance and trends of selected vertebrate species or groups, species richness		H	L	M	L	M	H	M	NA	L	NA	M
			Forest birds and bats	32	Some species are sensitive to environmental change processes, both natural and anthropogenic, and can act as indicators of specific changes. Because the parks are required to maintain populations of native species, monitoring the growth, distribution, and reproductive dynamics of more sensitive species provides an early warning for the welfare of the target species as well as that of associated species.	Are the demographics of selected native, endemic, or focal forest bird and bat species changing? If so, are changes deleterious, and can we control or reduce threats to these populations?	including demographic measures (size/age structure, reproduction, recruitment, etc.) and prevalence of disease, pathogens, and/or population threats. (Different methods for forest birds, raptors,	Population demographics, density, distribution. Prevalence of disease, pathogens, other population threats.		H	NA	H	NA	H	H	L	L	L	H	H
		Vegetation communities	Focal terrestrial plant communities	9	As a result of stressors such as invasive species or habitat fragmentation, entire native communities or assemblages may be depleted or locally extirpated. Early detection of changes in these communities will aid managers in threat mitigation, restoration and protection of habitat for rare and endangered species. Protection of Endangered and Threatened Species and their habitats is mandated by the Endangered Species Act.	Are there detectable changes in selected communities of interest? What is the relative abundance of native and non native species of vascular or non-vascular plants in communities of interest? What plant species and natural communities are rare in the parks? How do native plants respond to management activities? What are impacts of severe weather events on communities & focal species?	Transects, permanent plots, mapping, remote sensing, tagging.	Presence/absence, abundance of focal species and groups; diversity indices both within and across plant communities; Changes in structure, density, cover, recruitment, flower & seed production and trends in selected focal groups of plant species.	Includes T10-response to native plants to management (15), T9-community succession (32), T10(15)?, T6-effects of disturbance on terrestrial communities (82)	H	H	H	L	H	H	M	M	H	H	H

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Biological Integrity	Focal Species or Communities	Vegetation communities	Focal terrestrial plant species	3	Species that are highly sensitive to environmental variation act as indicators of natural and anthropogenic changes that may impact entire communities; their decline could serve as an early warning of ecosystem degradation. Threatened and Endangered species are an important aspect of biodiversity and parks are mandated (Endangered Species Act) to monitor their condition and implement recovery activities.	What are the distribution, abundance, and demographics of Threatened, Endangered, Rare, and focal native vascular and non-vascular plant species? Is the overall number of rare plant species increasing or decreasing? Are plant populations reproducing at sustaining levels? Is pollination, seed bank, seed set, and seedling recruitment adequate to maintain populations?	Mapping, plots, counts in size classes. Soil cores and subplots for seed banks. Flower and fruit monitoring at focal plant populations. Genetic analysis of focal species samples.	Phenology, survival, soil seed bank, population structure, distribution, density, reproduction. Genetic similarity of individuals in populations.		H	H	H	H	H	H	H	H	H	H	H
		Wetland communities	Wetland and riparian plant communities	18	The riparian community controls the amount of light reaching the water surface, and strongly influences nutrient cycling and transport, organic matter input, bank stability and stream channel morphology, and subsurface water flow into streams & wetlands. Historically in the PACN, low-lying wetland, riparian, and coastal areas were the first to be altered by human activities, so plant communities in these areas have often been significantly altered. Understanding changes in populations of wetland species is important for their restoration or maintenance.	What species are present? What are rates of production? What is the proportion of native vs. alien species contributing to productivity? What are rates of riparian input (leaf litter, etc.) into aquatic habitats? Are there long-term changes in wetland & riparian plant communities?	Periodic transects & plot surveys, mapping, litter traps, surface water sampling	trends in cover, density, size classes, litterfall, diversity over time, distribution, demographics, species composition, litter volume per species		H	M	L	H	H	L	H	H	H	H	L
	Infestations and Diseases	Animal diseases	Marine animal disease	35	Disease can directly kill or weaken organisms impairing their ability to survive other stressors. Disease can interfere with reproduction, growth and other organismal functions.	What are the prevalences and levels (how severe), and trends in known causes of morbidity and mortality in targeted populations? Where cause-effect is clearly established, are these affecting the populations?	Known causes: specimen and/or carcass collection (may include telemetry to recover carcasses), host or vector surveys/sampling, surveys of affected population to determine population status and impacts. Potential causes: Surveys in high risk sites, education.	Disease or threat prevalence, level, or presence/absence; distribution and numbers of host and/or vector species involved; abundance or density of affected population. Stage of disease/infestation, host condition.		L	M	H	M	M	L	M	M	H	H	L

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Biological Integrity	Invasive Species	Invasive/Exotic animals	Exotic aquatic animals-status and trends	36	Invasive aquatic animals can predate upon or compete for food with natives, alter habitat, or spread disease. An example of this is the introduction of water surface-feeding topminnows, which have a profound predatory impact on native aquatic insect larvae, in contrast to bottom-feeding native gobies (Englund 1999). The Invasive Species Act of 1996 mandates federal agencies to manage these species.	What is the present extent of occurrence? Are there changes in extent over time?	Periodic quadrat netting/trapping, visual transect censuses, mapping.	presence/absence, trends in abundance, distribution and density		L	L	M	NA	H	H	M	M	H	M	L
			Exotic invertebrates-status and trends	54	The establishment of different invasive animals has different consequences for native communities, depending on such factors as the invasive species' behavior and feeding and habitat preferences. Invasive aquatic species can either predate upon or compete for food with natives. Introduction of invasive aquatic species which occupy different ecological niches than natives can have indirect effects, such as introduction of parasites or alteration of habitat.	Are native plant and animal species' abundance or distribution changing in response to predatory or omnivorous invasives, or in response to efforts to control these invasives? What are trends in predatory and omnivorous invasive species populations?	Treatment and control transects, plots, or sites using appropriate methods to assess both invasive and native organisms of interest (VCP, transects, etc.), surveys for predators using appropriate methods to estimate population size and distribution.	Plants: species composition, population and/or community structure. Animals: abundance or density, possibly presence/absence, and/or other measures of critical life stages impacted by predators. Predators: population indices, presence/absence		L	L	H	L	L	H	L	L	L	L	M
			Exotic terrestrial invertebrates-early detection	15	Alien species invasions are much easier to control at an early stage than after they have become widespread. Preventing alien establishment and extirpating beachhead populations is especially important with invertebrates: without active monitoring, by the time they are detected the population is usually large and it is too late for the species to be effectively eradicated or contained	What potential high-impact species have breached the border-protection system and have potential to reach the park? What is the nature and extent of infestation? Is eradication/containment feasible and where should efforts be focused? Which species are present in park? What is the nature and extent of infestation? Where should efforts be focused? What are potential impacts?	Active monitoring (transects, plots, light trapping, etc.) in high-risk sites; rapid assessment of extent of infestation; mapping of new discoveries; education, outreach, and public reporting, follow-up on reports.	Identification & distribution of targeted 'blacklist' and other novel (previously undetected) invasives. Presence/absence, distribution, rapid assessment of extent of infestation		M	H	M	M	H	H	M	M	M	M	H

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Biological Integrity	Invasive Species	Invasive/Exotic animals	Exotic terrestrial vertebrates-early detection	11	Alien species invasions can impact native animals by predation, competition, facilitating the introduction of alien diseases and parasites, and by displacing food supply, roost sites or other important habitat components. Invasive species may be even more damaging to native species and ecosystems on a global scale than the loss and degradation of habitats.	What potential high-impact species have breached the border-protection system and have potential to reach the park? What is the nature and extent of infestation? Is eradication/containment feasible and where should efforts be focused? What are potential impacts? Is species present in park? If so, what is the nature and extent of infestation? Are native plant and animal species' abundance or distribution changing in response to the invasive or its control? What are the pathways and points of entry?	Detection: survey high-risk sites; follow up reports; education and outreach (public reporting). Impacts and response to treatment: treatment and control transects, plots, or sites using appropriate methods to assess both invasive and native species	ID & distribution of targeted 'blacklist' and other novel (previously undetected) invasives. Presence/absence; predator population indices and mapping; rapid assessment of infestation extent. Native plants: species composition, population status		M	H	M	H	H	H	M	M	H	M	H
			Exotic ungulates-status and trends	39	Ecological damage from exotic invasive species includes impacts to native flora and fauna, natural disturbance regimes, and ecosystem functions. Invasive species jeopardize the sustainability of threatened and endangered species and may cause loss of more common species.	What are the relative abundance, distribution, and population trends of feral ungulates? Are native plant and animal species' abundance or distribution changing in response to feral ungulates, or in response to efforts to control feral ungulates?	Treatment and control transects, plots, or sites using appropriate methods to assess both invasive and native organisms of interest (VCP, transects, etc.); surveys for predators to estimate population size and distribution. Treatment trials.	Plants: species composition, population and/or community structure. Animals: VCP, abundance or density, possibly presence/absence, and/or other measures of critical life stages impacted by predators. Predators: population indices, presence/absence		NA	H	H	NA	H	H	L	L	L	M	M

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Biological Integrity	Invasive Species	Invasive/Exotic plants	Exotic aquatic plants-status and trends	21	Alien plant and algal species can serve as important indicators of ecosystem health. Invasive plant and algal species can impede water flow (filamentous algae and grasses), increase sediment deposition (mangrove and grasses), change patterns of organic matter input (fruit-bearing or nitrogen fixing plants), exclude native plants, and provide an inferior food source for aquatic herbivores. The Invasive Species Act of 1996 mandates federal agencies to manage these species.	What is the present extent of occurrence? Are there changes in extent over time?	Periodic transects & plot surveys, mapping.	presence/absence, trends in abundance, distribution and density		H	H	L	H	M	M	H	H	H	M	L
			Exotic terrestrial plants- early detection	4	Early detection of incipient alien species of plants & fungi allows for proactive and cost-effective management. Eradication projects are likely to be more effective if invasive species are detected early. Identification of characteristics of high impact invasives (habit, taxonomic group, dispersal method) will aid in identification of other potential invaders.	What potential high-impact species have breached the border-protection system and have potential to reach the park? What is the mode of dispersal through which the species entered the park? What is the nature and extent of infestation? Is eradication/containment feasible and where should efforts be focused?	Shared surveillance by multiple agencies and public, including follow-up on reports; surveys in high-risk sites inside and outside parks (e.g. roadsides, trails, ports, disturbed sites). Observations of seed dispersers and collection of seed rain information.	Presence/absence, assessment of extent of infestation. Density and size class of impacted native plant populations. Species composition of affected native communities. Species composition of seedbanks. ID and distribution of targeted "blacklist" species		M	H	H	H	H	H	H	H	H	H	H
			Exotic terrestrial plants-status and trends	1	In Pacific Island Parks, alien plant species have altered many ecosystems of cultural landscapes by displacement of native species, habitat fragmentation and disruption of ecosystem processes. Monitoring established alien plants allows park managers to improve strategies to control or eradicate them and restore natural vegetation.	What is the distribution and abundance of established alien plants (including mosses)? What is the rate of spread of alien plants? What is the relative abundance of native and invasive species? What are the impacts on native species of vascular and nonvascular plants? What is the potential of alien plant species to invade and dominate communities?	Mapping, transects, plots, counts in size classes. Soil cores and subplots for seed banks.	Distribution mapping, frequency, cover, density and population structure of alien and native species. Species composition of seedbanks.		H	H	H	H	H	H	H	H	H	H	H

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Ecosystem Pattern and Processes	Fire	Fire and fuel dynamics	Fire dynamics	47	Fire impacts all aspects of ecosystems at a landscape level including conversion of vegetation types, wildlife and food resources, nutrient cycles, and water quality/quantity. Plant communities vary in their response to, and recovery from, fire. Improved understanding of fire dynamics will aid in Fire Management programs and Resources Management planning.	What is the current or recent fire regime? What is extent & intensity of fires? What are current natural and anthropogenic ignition sources ? What are the impacts of fire on landscape pattern and patch viability? What are the implications to plant community composition and structure resulting from fire? What are impacts to threatened, endangered and SOC species of plants? What are impacts of fire to vertebrate and invertebrate groups?	Transects, plots, histories, mapping. Erosion pins and sediment collectors for erosion monitoring. For Community Level questions: Transects, plots, population surveys of focal plant, vertebrate and invertebrate species.	Change in vegetation structure, erosion, or nutrient loss following fire, landscape history. For Community Level Questions: Change in vegetation structure, cover, density, vigor, size classes, recruitment rates, growth rates, species composition, presence		NA	H	NA	NA	M	H	M	M	M	M	M
	Land Cover / Land Use	Land cover / Land use	Land use patterns	5	Alterations in land use and its intensity of use may contribute to and be indicative of pollution of water and air resources, fragment habitat, alteration of migratory patterns of birds, increase soil erosion, and the introduction exotic invasive species.	What areas are most at risk due to conflicting adjacent changes in land use (e.g. ranching, urbanization)? What land use changes are occurring within and adjacent to the park (trends in use types)? What are the predicted impacts of land use changes on park values? Are there detectable changes within park due to land use.	Aerial photography, mapping, plots	change detection maps, area & distribution of change	Includes H10-subsistence farming (94).	M	M	H	H	H	H	H	H	H	H	H
			Wilderness use	65	Monitoring of 'wilderness character' is mandated by the Wilderness Act.	Are wilderness areas / character being unacceptably changed?	Limits of acceptable change. Nature, magnitude, and source of impacts	Limits of Acceptable Change (LAC)		NA	NA	NA	NA	NA	H	NA	NA	NA	NA	L

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Ecosystem Pattern and Processes	Lightscape	Lightscapes	Lightscapes	41	Light pollution can negatively impact visitor experience as well as biological resources.	Are natural light/dark cycles maintained as appropriate (e.g. no inappropriate shading)? Is artificial light appropriately shielded? Is artificial light restricted to basic human safety needs only? What is impact on night sky from artificial light sources outside the park?	Above ground (aerial or satellite) vs. on ground measurements (photographs) of artificial light sources within park, calibrated/repeatable.	Light intensity, spatial distribution, temporal frequency, color. Baseline not greater than 10% deviation.		M	L	L	M	M	H	M	M	M	M	M
	Nutrient Dynamics	Nutrient cycling	Nutrient cycling	37	Nutrient cycles are essential ecosystem processes and the linkages to decomposition are complex and important. The carbon cycle is an essential ecosystem process, where insects, animals, saprophytes, pathogens and fire all play important roles in nutrient cycles. Nutrient cycles link the biotic and abiotic components of an ecosystem through a constant change of materials. As such, these cycles may be considered an integrating variable, since they occur across scales and involve the atmosphere, biosphere, lithosphere, and hydrosphere. While nutrients may be transported great distances in water or air, the key transformations that make these elements available to plants (and so to animals) are driven by soil microbes, as are the reactions that release the elements back to air or water, to repeat the cycle. In most cases, well established ecosystems have very "tight" nutrient cycles that conserve key nutrients. Human activities such as forest harvesting, fire suppression, disease introduction and/or control may disrupt these cycles leading to reduced availability of nutrients and a loss of	How are processes changing over time (source, directions, levels of flow)?	monitoring plots	Aquatic senescence, Coral growth-CaCO3 deposition, Forest productivity (litter rain, incremental growth), Key constituents (N, K, CaCO3)	Need to define what systems-still unclear on what habitats this is going to be done in. very different methods would be involved. isn't this really research in different communities?	M	M	M	M	M	M	M	M	M	M	M
	Soundscape	Soundscapes	Soundscapes	39	Noise pollution can come from a variety of sources. Anthropogenic noise pollution includes aircraft, automobiles, other visitors, and activities external to the park. Natural sources can be lost (native bird calls, running water), or alien species can introduce noise.	What type of alien sounds are present in respective management zones? What are sound levels? Are alien sounds appropriate to management zone? Are naturally present sounds maintained at appropriate frequencies, occurrence, db levels? Are we exceeding an acceptable level of sound?	point/plot sampling	frequency (hz), frequency (time), Sound durations, Sound levels, sound source identification, spatial distribution		L	L	L	M	M	M	M	M	H	M	M

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Geology and Soils	Geomorphology	Coastal / oceanographic features and processes	Shoreline Change	26	Change in shoreline morphology affect both coastal and marine resource, such as wetlands, tidepools, coral reefs, and seagrass beds.	Where are shorelines advancing, retreating, or stable, and what is the rate of change?	historical shoreline analysis (air photos, T-sheets), beach profiles, tide gauge data to examine local sea-level trends, field observations and measurements	human development/infrastructure, substrate composition, shoreline aspect/position/slope, sea level, nearshore physical oceanography, historical shoreline analysis, amount of change (m) over the time span between measurements (years).		M	L	L	H	H	H	H	H	H	H	L
		Windblown features and processes	Dunes	66	Affect resource / habitat as well as recreational (terrestrial & marine uses).	Are drought & desertification influencing topsoil transport and seed/nutrient transport patterns?	remote sensing, field investigation, periodic change analysis	grain size & parent material, rainfall, soil crust development, substrate composition, substrate distribution, veg stabilization, wind regime		NA	NA	NA	NA	NA	NA	NA	NA	NA	H	L
	Soil Quality	Soil function and dynamics	Erosion and Deposition	29	Erosion and sedimentation are directly indicative of soil disturbance and provide a good indicator of the rate or extent of land use change. When suspended in water, fine sediments increase turbidity, decrease light penetration, and alter primary productivity. In some cases excessive sediment accumulation can alter the hydrologic regime.	What are causes and locations of soil erosion, what are rates of change, what is land use and human impact?	erosion pins deployed together and integrated over watershed, sediment collectors, mapping, sediment fingerprinting	Areal distribution of rate of soil loss (mapping), transport out of watershed		M	H	L	M	M	H	M	M	M	H	L

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Geology and Soils	Subsurface Geologic Processes	Caves / karst features and processes	Cave habitat	51	Environmental conditions in caves and lava tubes are easily disturbed by human activity. However, caves and lava tubes are often important traditional cultural sites in Hawaii and elsewhere.	How do natural/human induced impacts affect environmental cave conditions (temp, humidity, light, etc.)? How do human activity & cultural practices impact cave systems above ground outside and inside?	Station/plot data, photo points (repeat photography)	Litterfall, species distribution & abundance, human use levels, temperature, humidity, ground compaction, etc.		NA	H	L	NA	L	M	M	M	L	M	M
		Seismic activity	Seismic activity	56	Non-volcanic seismicity is a hazard.	Can we identify trends and predict hazards?	Seismometers (local and global)	tilt meters, seismometers, dilatometers (pressure gauges), EDM (Electronic Distance Measuring)	Combines both P39-volcanic seismicity (92) and P38-non-volcanic seismicity (91).	L	L	L	L	M	M	L	L	L	L	L
		Volcanic features and processes	Lava flows	61	Volcanic activity is a hazard.	What role do lava flows play in maintaining public safety, park facilities, and how do they affect natural processes?	Remote sensing, visual observation, tilt meters and dilatometers, GPS ground deformation	tube mapping, flow direction/magnitude, GPS		NA	NA	NA	NA	NA	M	M	M	L	L	M
			Mass wasting	57	Mass geologic wasting is a hazard.	Can we predict slope failure hazards to protect habitats and human safety? Can we monitor or identify causes? What are temporal trends?	Rainfall and other climactic analyses (precursors and catalysts), stream gauges, remote sensing	soil saturation, soil/ground creep, substrate composition/perm eability, substrate distribution		NA	L	M	NA	M	M	M	M	L	L	L
Human Use	Consumptive use	Consumptive use	Fisheries Harvest	38	In the Pacific, a wide diversity of marine species are fished for consumptive uses and fishing is well documented to have significant impacts on ecosystem structure and function, and on the condition of resources. Fishing is increasingly documented as being the principal threat to Pacific coral reefs and other marine ecosystems worldwide. Currently fishing is allowed in PACN parks following established state/territorial regulations.	What are the trends in the harvest of fisheries species? Harvest includes legal and illegal take.	Systematic monitoring of fishing in park on species and harvest of shellfish and other inverts in coastal areas, creel surveys	CPUE (control & harvested population), collection statistics (quantity, age/size), composition		L	H	H	L	H	L	L	L	H	H	L
	Cultural Landscapes	Cultural Landscapes	Viewscales	45	Class 1 parks have designated viewsheds.	Are landscapes/seascapes changing in and surrounding the park? If so, how?	historical photos (periodic photography from fixed points)	qualitative, % of change, presence/absence	no WASO equivalent?	NA	NA	L	M	M	H	M	M	M	H	M

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Human Use	Point-Source Human Effects	Point-source human effects	Litter and debris	30	Litter and debris can be physically harmful to animals and plants, particularly by entanglement. Presence of litter diminishes visitor experience. International Convention for the Prevention of Pollution from Ships (MARPOL) 1973, 1978 controls five types of pollution caused by ships: oil and oil products, noxious liquids carried in bulk, harmful packaged substances, sewage and garbage.	What are levels of litter within parks? Where is littering/ dumping of trash taking place (e.g. terrestrial, open ocean)? Where are areas of marine debris deposition?	surveys of activity & locations, identify spatial distribution, document/characterize source	quantity presence / absence, type & size	Marine debris is not a point-source issue.	M	M	L	H	M	H	M	M	H	L	L
	Visitor and Recreation Use	Visitor usage	Terrestrial visitor usage	16	Human impacts can include habitat, successional stages, structural differentiation, nutrient cycles, forage availability, water quality/quantity yields, successional pathways, wildlife variety and quantity, carbon balances, and scenic variability. Human actions can significantly alter the extent, intensity, duration and periodicity of disturbance events (e.g. excessive grazing over a number of years, permanent vehicle traffic routes through sensitive sites, annual spraying pesticides, removing vegetation altering snow accumulation and runoff timing, etc.). Human actions can lead to disturbance rates that outstrip the ability of biological systems to respond and/or recover from the resulting changes. Human activity or interventions in the environment must take into account the recovery ability of ecosystems and normal patterns of disturbance at the landscape scale to assure that any proposed disturbance will be within normal recovery capabilities of the system.	Are locations and/or intensity in use areas (visitor or management) changing? Are use levels associated with detectable levels of resource change?	VERP program, repeated mapping of use areas, plot sampling	erosion, plant cover, quantify use levels		H	L	L	H	H	H	H	H	H	L	
Water	Hydrology	Groundwater dynamics	Wetland hydrology	31	An understanding of wetland hydrology is required for predicting the effects of natural and human-induced hydrological changes (e.g., sea level rise, drought conditions, municipal groundwater withdrawal) and the fate of contaminants on wetland systems. The NPS is required to protect wetlands under E.O. 11990	What are freshwater/saltwater recharge rates? What is habitat extent and distribution? What are temporal trends in recharge rates and habitat extent? What are groundwater levels, residence times, infiltration, permeability, and evaporation rates in wetlands? What is the relationship between groundwater and wetlands in anchialine pools?	measure salinity, residence time, mapping, samples from wells	plant cover/ species present & extent, pool size, extent, depth & salinity, rainfall, sediment loads, pH, tidal fluctuation	This VS contains a large groundwater component. May want to delete "groundwater dynamics" vital sign.	H	L	L	NA	M	M	H	H	M	M	

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Water	Hydrology	Marine hydrology	Marine Hydrography	23	An understanding of marine hydrology is important in predicting the effects of storms and high wave events on marine resources.	What is the natural variability? What are temporal trends? What are the frequency, magnitude and distribution of marine inundation events? What park resources are subject to inundation during tsunamis and large storms or big wave events?	tide gauge, ADCP, GIS, buoy data, satellite data, seismic networks, field mapping of water and debris lines (both horizontal incursion and vertical elevation)after an event, photograph damage and changes to park resources	maximum signal wave height, relative sea level, tide fluctuations, sea & storm surge levels, erosion/deposition	Includes P41-Extreme events (61).	M	M	H	H	H	M	M	M	M	H	L
	Water Quality	Toxics	Toxics and Contaminants	6	Toxics and contaminants reaching water resources negatively affect aquatic biota, human health, and local economics. Early detection is important to offset impacts from off-site pollution.	What are the range and variance of toxics and contaminants in surface water? What are the temporal and spatial trends?	water sampling, sediment sampling, animal tissue sampling, [GW: monitoring & supply wells, fat bags (SPMDs)]	chemical oxygen demand, heavy metals, herbicides, organics, pesticides, bioassays	Includes P32-marine (23) & P31-groundwater (48).	H	H	M	H	H	H	H	H	H	H	L
		Water chemistry	Water quality core parameters	2	These parameters provide required minimum baseline data for water quality assessment that will be used throughout the National Park Service. Total nitrogen, total phosphorous, chlorophyll a, and depth were added due to their ecological significance in the Pacific Network.	What are the range and variance of the network core water quality parameters? What are the temporal and spatial trends?	in-situ measurements and collection of samples at established sites including controls	temperature, pH, salinity (sp. cond.), dissolved oxygen, PAR, total nitrogen, total phosphorous, chlorophyll a, depth	Includes P23-Marine (9) & P22-Groundwater (45).	H	H	H	M	H	M	H	H	H	H	M
			Water quality supplemental parameters	10	These parameters provide important details for characterizing water resources, identifying potential stressors, and detecting changes early.	What are the range and variance of the supplemental water quality parameters? What are the temporal and spatial trends?	in-situ measurements and collection of samples at established sites including controls	inorganic nutrients (NO2/NO3, PO4, NH4), suspended sediments/turbidity /secchi disk, alkalinity, anions, cations, redox, total organic carbon, chlorophyll b, chlorophyll c	Includes P26-groundwater (24) & P25-marine (66).	H	H	H	H	H	M	H	H	H	H	L